Sonographic Evaluation of Diaphragmatic Motion:

A Practical Guide to Performance and Interpretation

Benjamin D Smith
Hansel J Otero
Tara K Cielma
Anjum N Bandarkar

Children's National Health System,
Washington D.C.

GW

Children's National

Disclosures

None

Purpose

- Discuss the use of ultrasound for evaluation of diaphragmatic motion
- Illustrate sonographic technique and protocol for assessing diaphragmatic motion
- Case-based review of the spectrum of normal and abnormal diaphragmatic motion

Children's National

Background: Diaphragmatic Motion

- The diaphragm is the major muscle used during respiration
- Diaphragm motion abnormalities result in significant morbidity in infants and young children, because they are totally dependent on the diaphragm for ventilation
- Plain chest radiographs have low sensitivity for paralysis

- Fluoroscopic evaluation disadvantages:
  1. Radiation exposure
  2. Difficulty transporting critical patients to Fluoroscopy suite
  3. Potential confusion of phases of respiration
  4. Inability to visualize entire diaphragm
  5. Lack quantification of diaphragmatic excursion

- Epelman M et al. Pediatric Radiology 2005; 35(7):661-7,

Children's National

Diaphragmatic Dysfunction: Presentation

- Clinical presentation may be nonspecific and varied:
  - Persistent hemidiaphragm elevation on radiographs
  - Unexplained respiratory distress
  - Difficulty weaning from mechanical ventilation
  - Recurrent lung unilateral collapse or pneumonia

- Early diagnosis allows to:
  - Minimize prolonged ventilatory support
  - Plan early surgical plication

- Epelman M et al. Pediatric Radiology 2005; 35(7):661-7,
- Mong A et al. Pediatric Radiology 2012; 42(11):1287-97
- Chavhan GB et al. Radiographics 2010; 30(7):1797-817

Children's National

Advantages of Ultrasound

- Lack of ionizing radiation
- Dynamic, real-time imaging without sedation
- Easy to perform bedside
- Ability to quantify diaphragmatic excursion
- High resolution transducers, Tissue harmonics, Panoramic imaging, B-mode and M-mode make ultrasound a useful tool
- Children are better suited for US evaluation (improved acoustic window and lack of body wall fat)

- Epelman M et al. Pediatric Radiology 2005; 35(7):661-7
- Mong A et al. Pediatric Radiology 2012; 42(11):1287-97
- Chavhan GB et al. Radiographics 2010; 30(7):1797-817

Children's National

Sonographic Technique

- Evaluation is performed during quiet breathing
- If mechanically ventilated, ventilator is temporarily stopped to assess spontaneous breathing (i.e. requires assistance from respiratory therapist)

- 3 ultrasound methods are used:

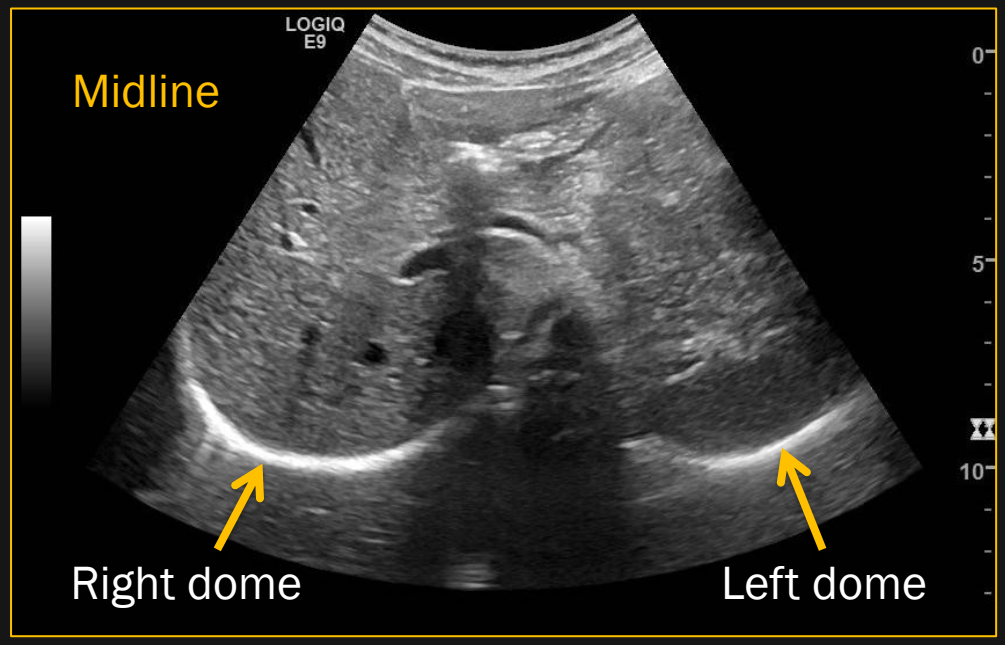
1. B-mode sonography
2. M-mode sonography
3. Cine imaging

Children's National

Sonographic Technique

B-mode sonography -

- Direct visualization of entire diaphragm
- Comparative simultaneous imaging of both domes
- Evaluating other causes of dysfunction/underlying pathology (e.g. hernia, mass, effusion and eventration)

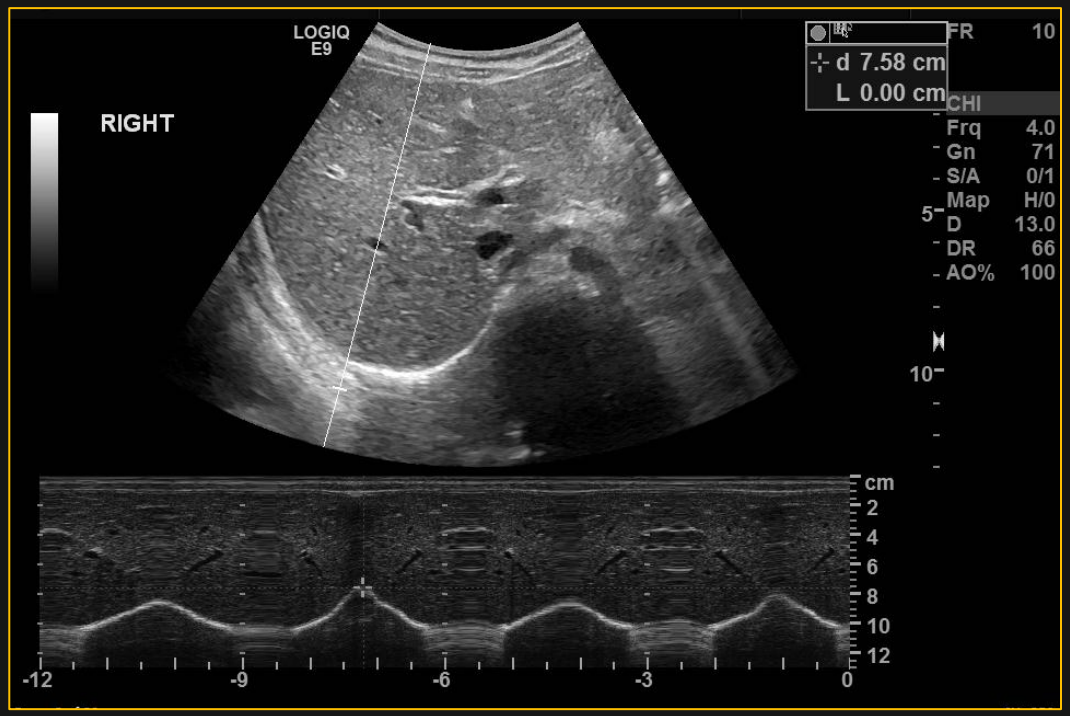


Children's National

Sonographic Technique

M-mode imaging

- Quantitative assessment of diaphragmatic excursion
  - Normal, Decreased, or Absent
- Evaluates direction of diaphragmatic motion
  - Normal, or Paradoxical

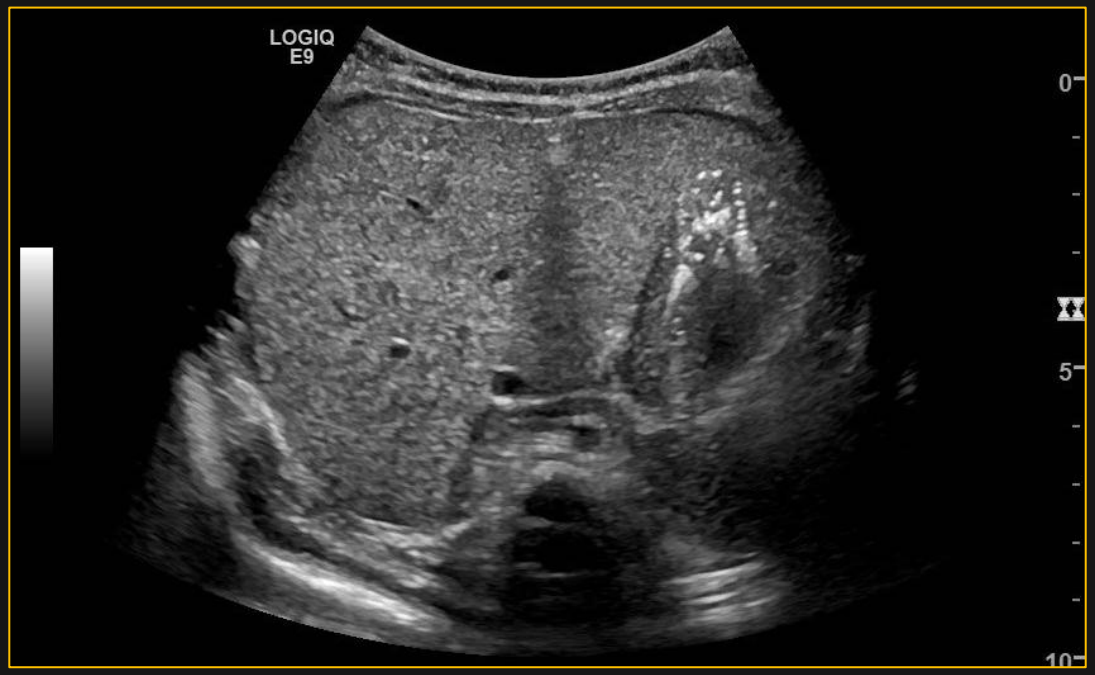


Children's National

Sonographic Technique

Cine Imaging

- Provides real-time information for observation and records for both the radiologist and clinician



Link to video: https://youtu.be/a9nEnt8cyLs

Children's National

Diaphragm Ultrasound Protocol

- Indication: Suspected diaphragmatic paralysis
- Preparation: Review prior chest radiographs
- Transducer:
  - Convex 1-6 MHz sector probe for diaphragmatic motion
  - Linear high frequency probe for underlying lung lesions
- Position: Supine or semi-recumbent

Children's National

Diaphragm Ultrasound Protocol

1. Ensure that breathing is unassisted

2. Start with convex transducer in the midline subxiphoid location, assess quiet respiration including both domes. Capture a ~5 second B-mode cine clip

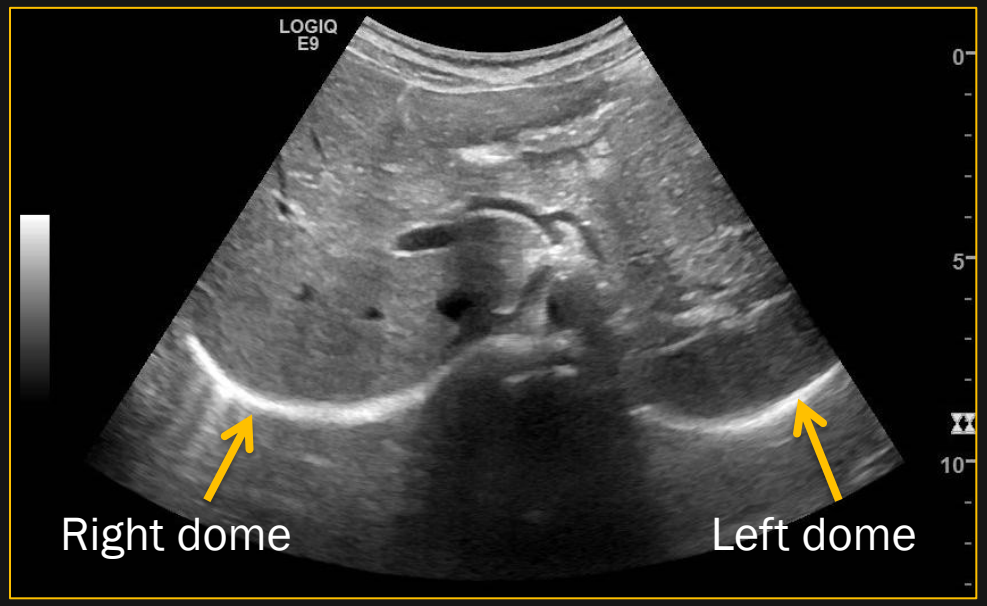
3. Use M-mode to document diaphragmatic excursion, one side at a time via tranverse subxiphoid and lateral subcostal approach. Place cursors at end of expiration and peak inspiration. Do not change scale! Left dome is more difficult to obtain due to GI gas

4. In case of eventration, document contour bulges from anterior, lateral and posterior approaches. Save B-mode cine clips as well as M-mode tracings of the eventrated diaphragm

Children's National

Diaphragm Ultrasound Protocol

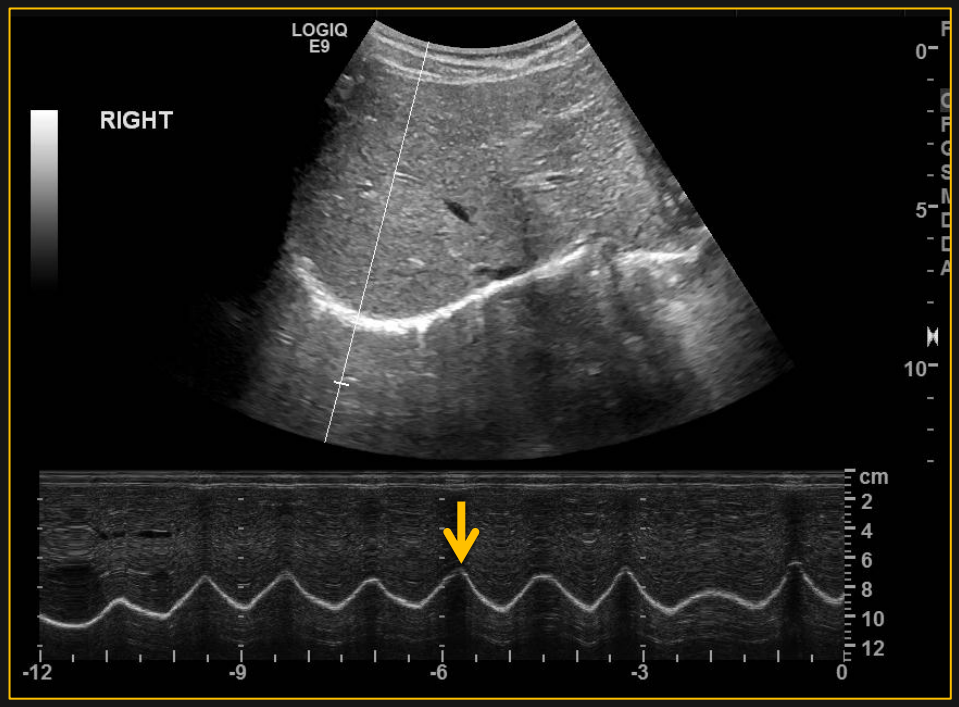
- Midline Approach: transverse subxiphoid view

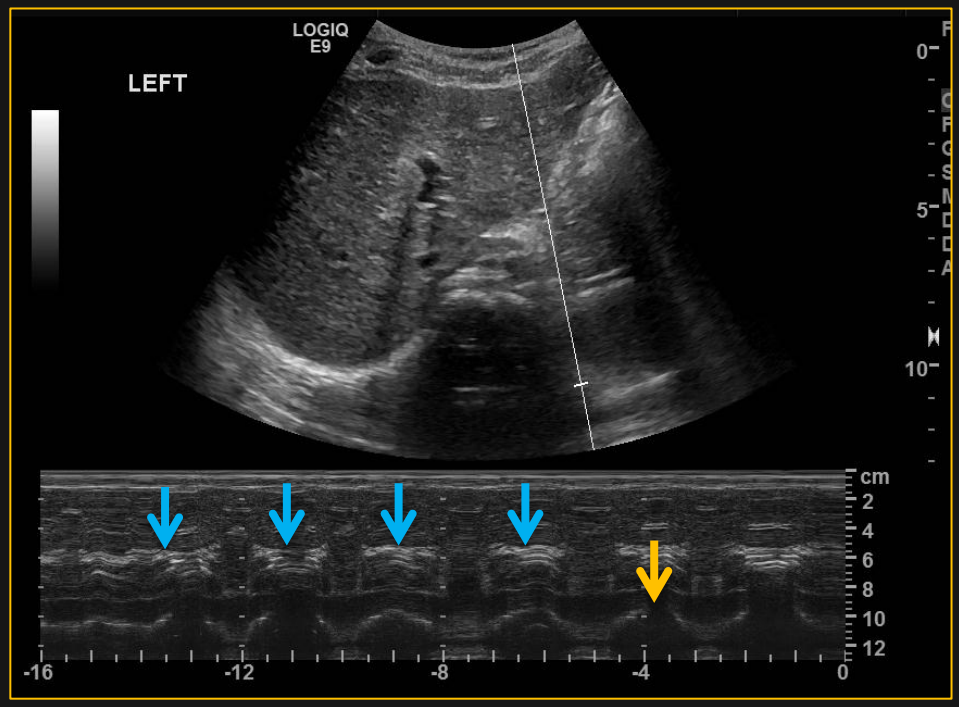


Children's National

Diaphragm Ultrasound Protocol

- Midline Approach: transverse subxiphoid view





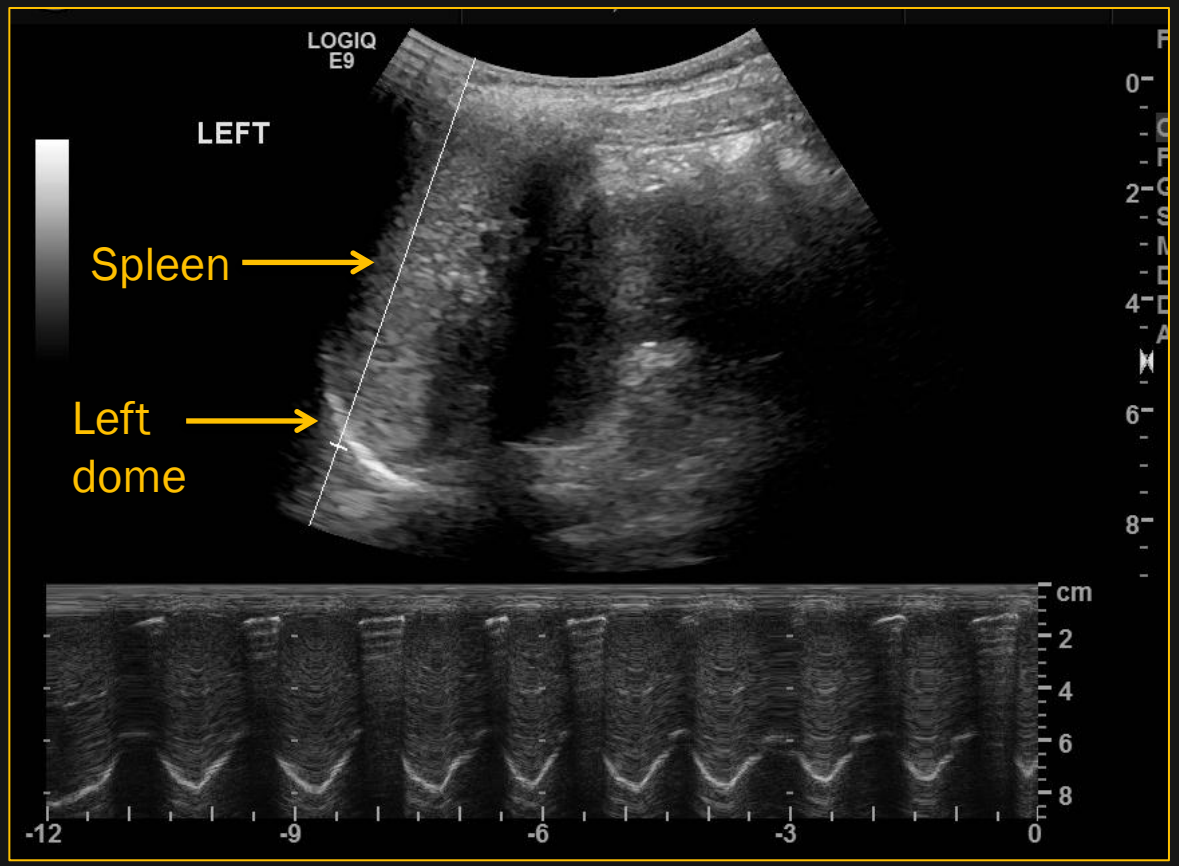
Right dome M-mode tracing is robust.
This is an 8 year old healthy volunteer

Left dome tracing harder to obtain.
Note artifact from stomach gas

Children's National

Diaphragm Ultrasound Protocol

- Subcostal Approach: Lateral subcostal view, one side at a time



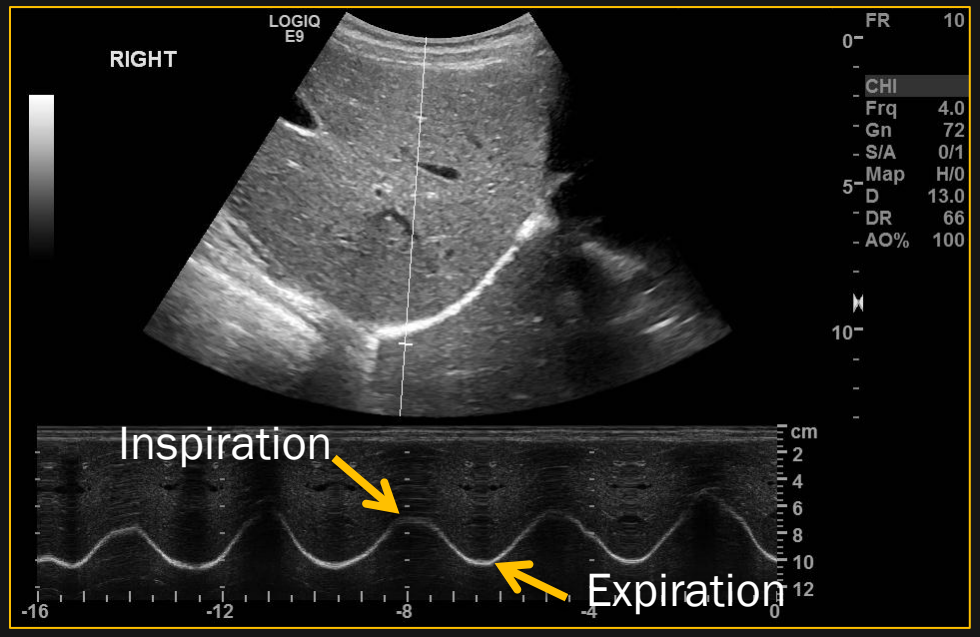
Children's National

M-mode of Diaphragmatic Excursion

- 2-D portrayal of diaphragmatic motion charted on real-time graph
  - Y-axis

    INSPIRATION Upward (+) = Motion toward transducer

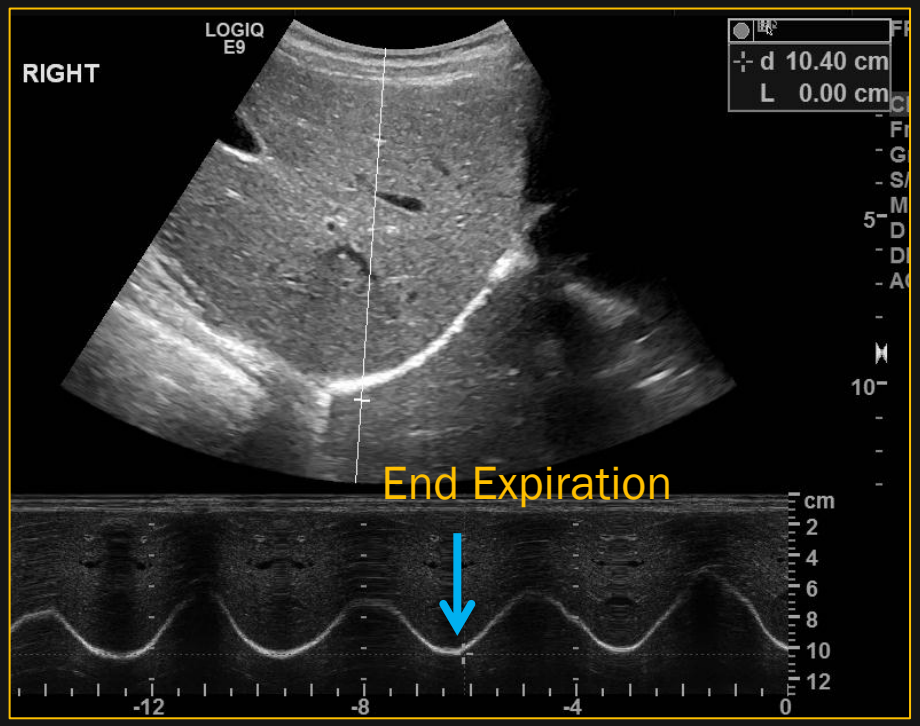
    EXPIRATION Downward (-) = Motion away from transducer
  - X-axis = time

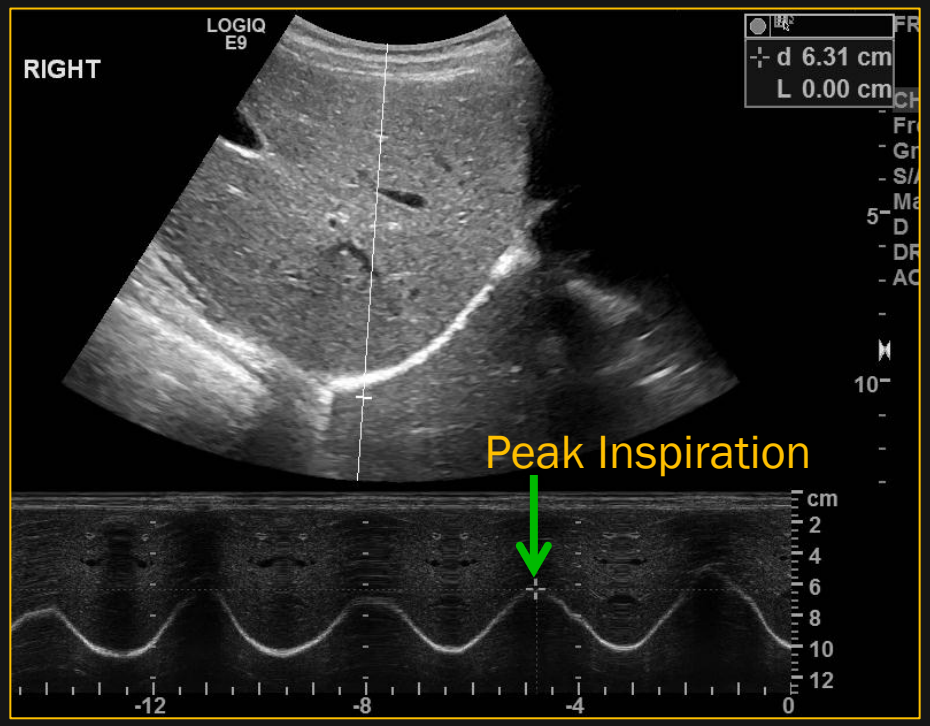


Children's National

How to measure Diaphragmatic Excursion

- First cursor placed at end of expiration
- Second cursor placed at peak inspiration
- Difference in cm gives excursion





Dome excursion = 10.4 - 6.3 = 4.1 cm

Children's National

Diaphragmatic Excursion on M-mode sonography

- Normal
  - > 4 cm
  - < 50% difference between hemidiaphragms
- Diminished (Weakness, Dysfunction)
  - < 4 cm or
  - > 50% difference between hemidiaphragms
- Absent
  - No movement

Children's National

Case-based Review – Diaphragm Ultrasound

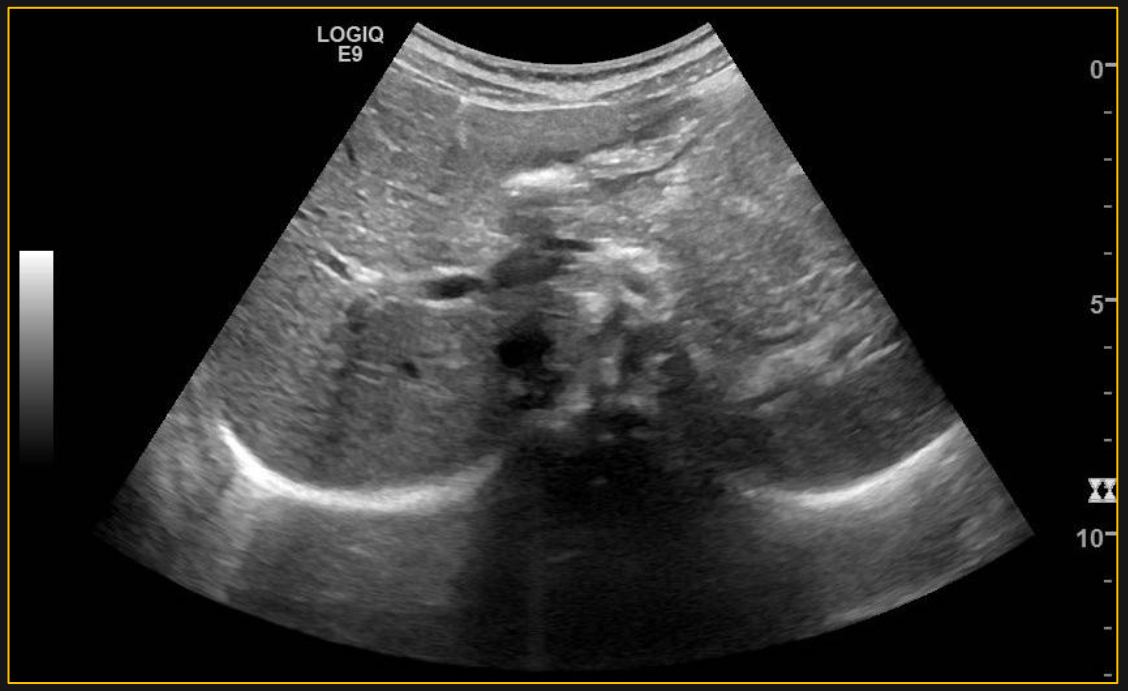
1. Normal diaphragmatic motion
2. Diminished motion (Weakness or diaphragmatic paresis)
3. Diminished Motion prior to extubation
4. Absent Motion (Unilateral or Bilateral paralysis)
5. Paradoxical Motion
6. Eventration

Children's National

Normal diaphragmatic motion

Case 1: 8 year old girl healthy volunteer

Link to video: https://youtu.be/ISwvnvL2LQE

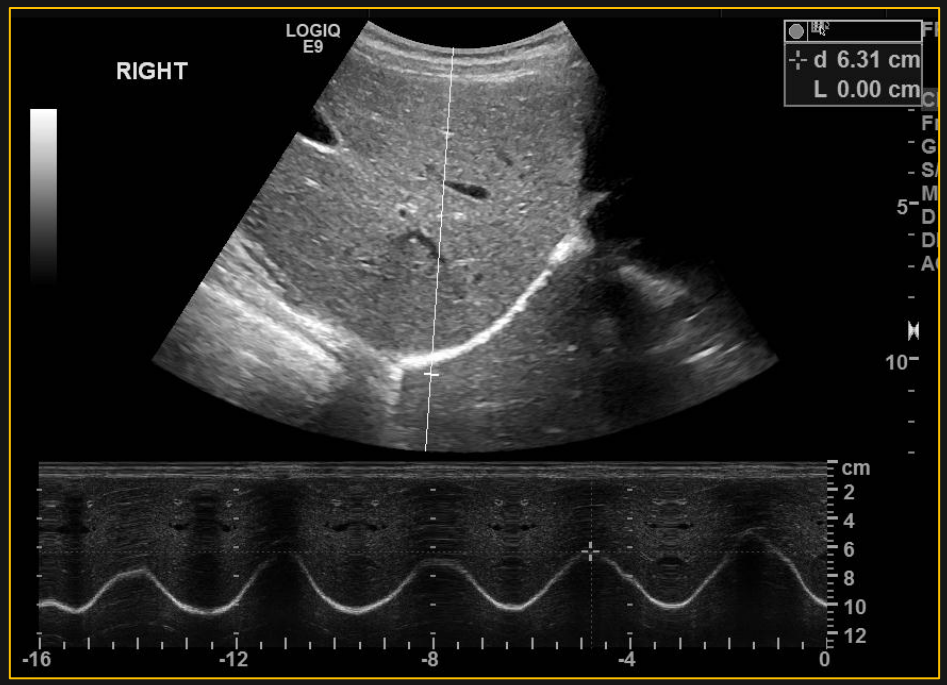


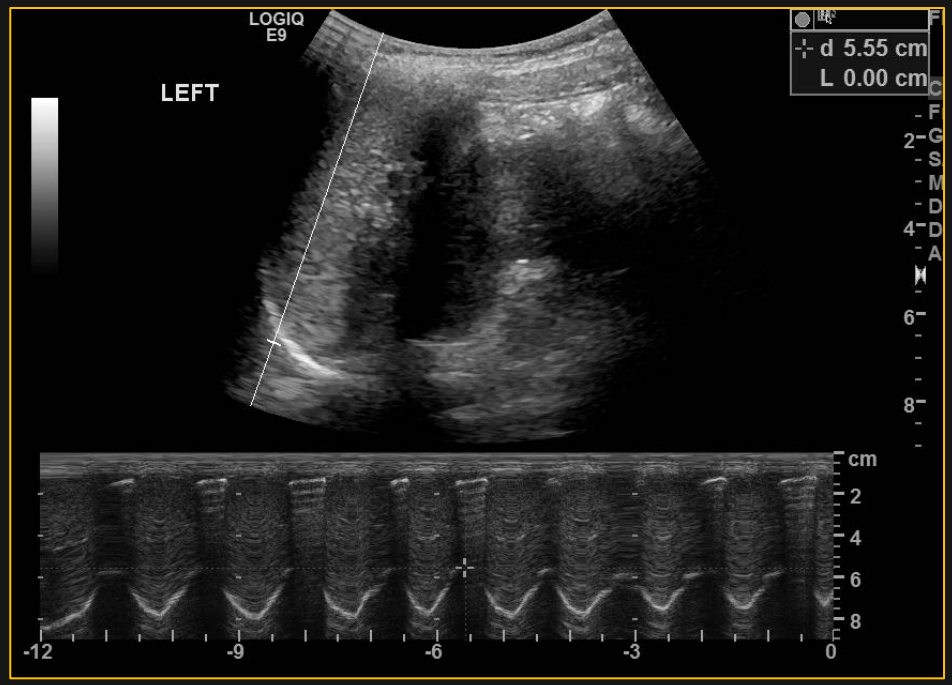
Midline approach- Symmetric motion of both hemidiaphragms

Children's National

Normal diaphragmatic motion

Case 1: 8 year old healthy volunteer



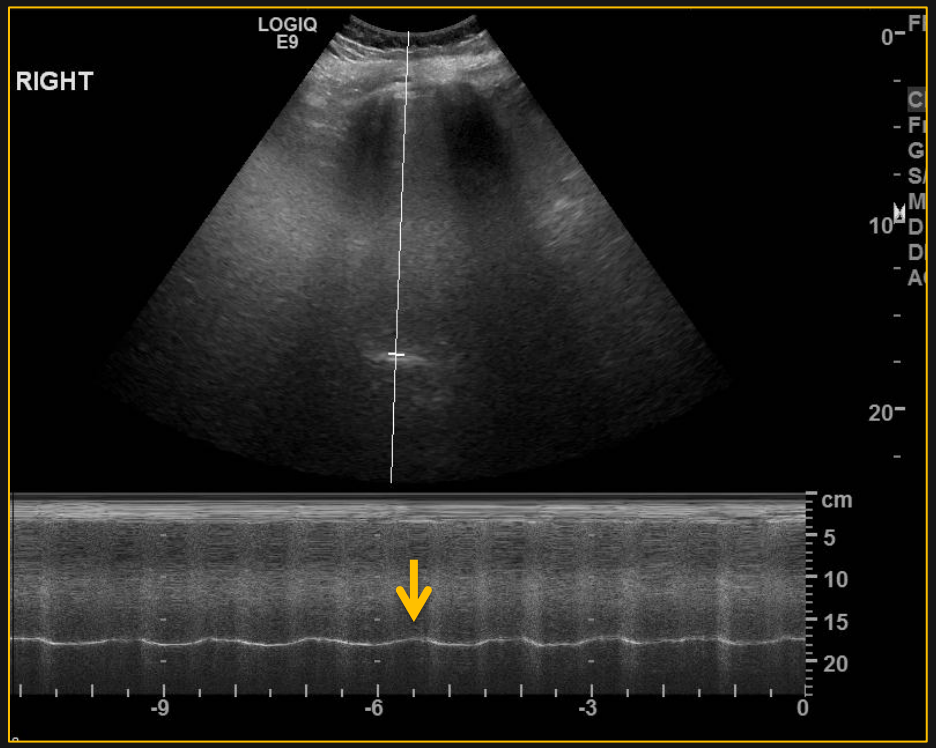


Subcostal approach- M-mode tracings of both domes

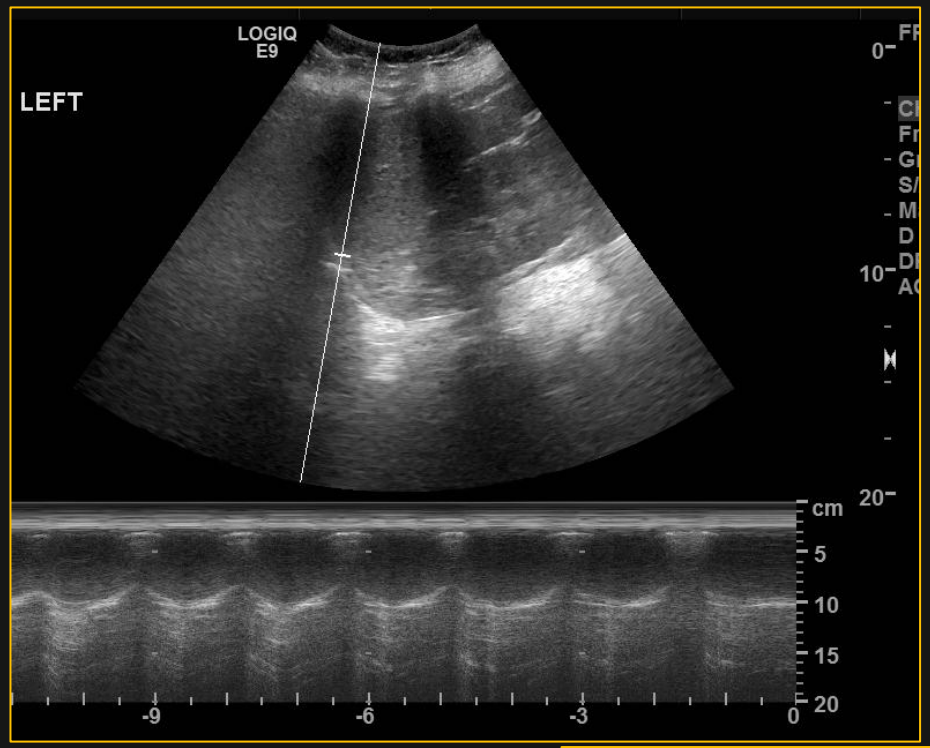
Children's National

Diminished Motion – Diaphragmatic paresis

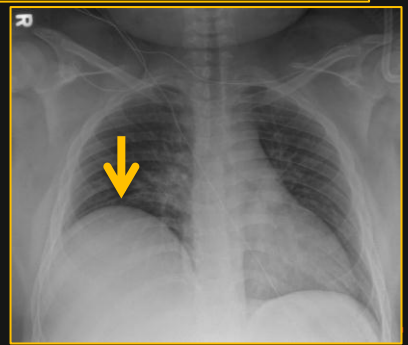
Case 2: 12 year old boy, failure to extubate after tonsillectomy



Right hemidiaphragm shows minimal motion and blunted M-mode tracing, consistent with paresis



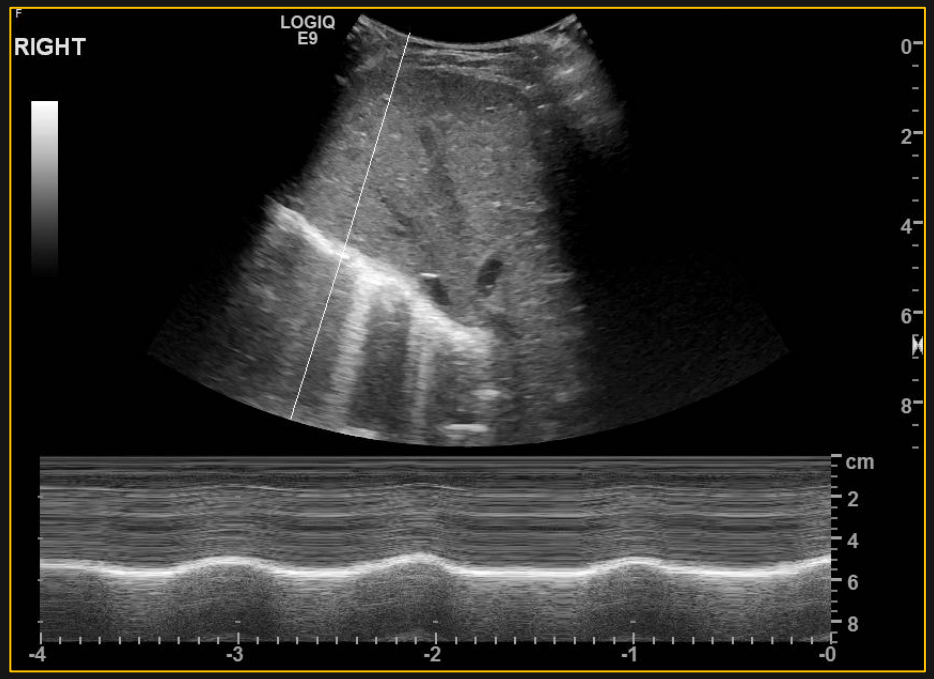
Left hemidiaphragm shows normal motion



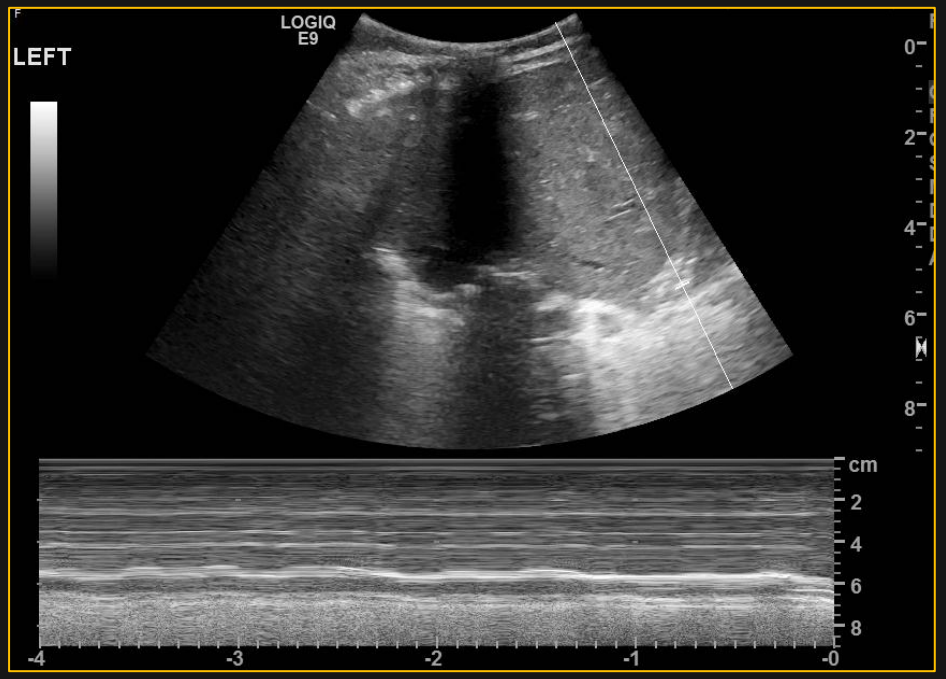
CXR – Elevation of right dome

Diminished Motion – Diaphragmatic paresis

Case 3: 4 month old baby, post cardiac surgery. Need to evaluate diaphragmatic motion prior to extubation



Normal movement of right hemidiaphragm



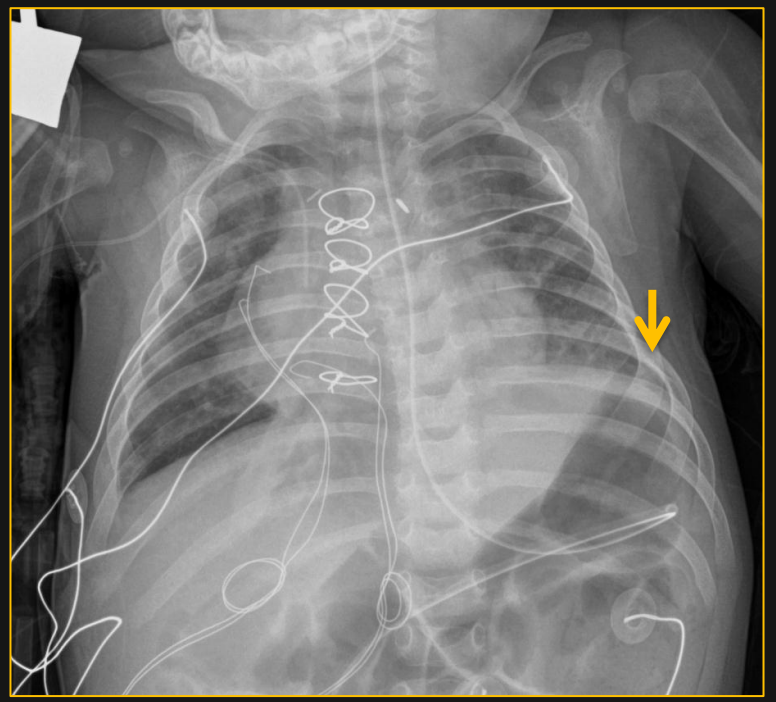
Minimal movement of the left hemidiaphragm, >50% less than the right, consistent with diaphragmatic paresis

Children's National

Diminished Motion – Diaphragmatic paresis

Case 3: 4 month old baby for evaluation of diaphragmatic motion prior to extubation after cardiac surgery

On ventilator, with ET tube in place



Post extubation- Elevated left dome

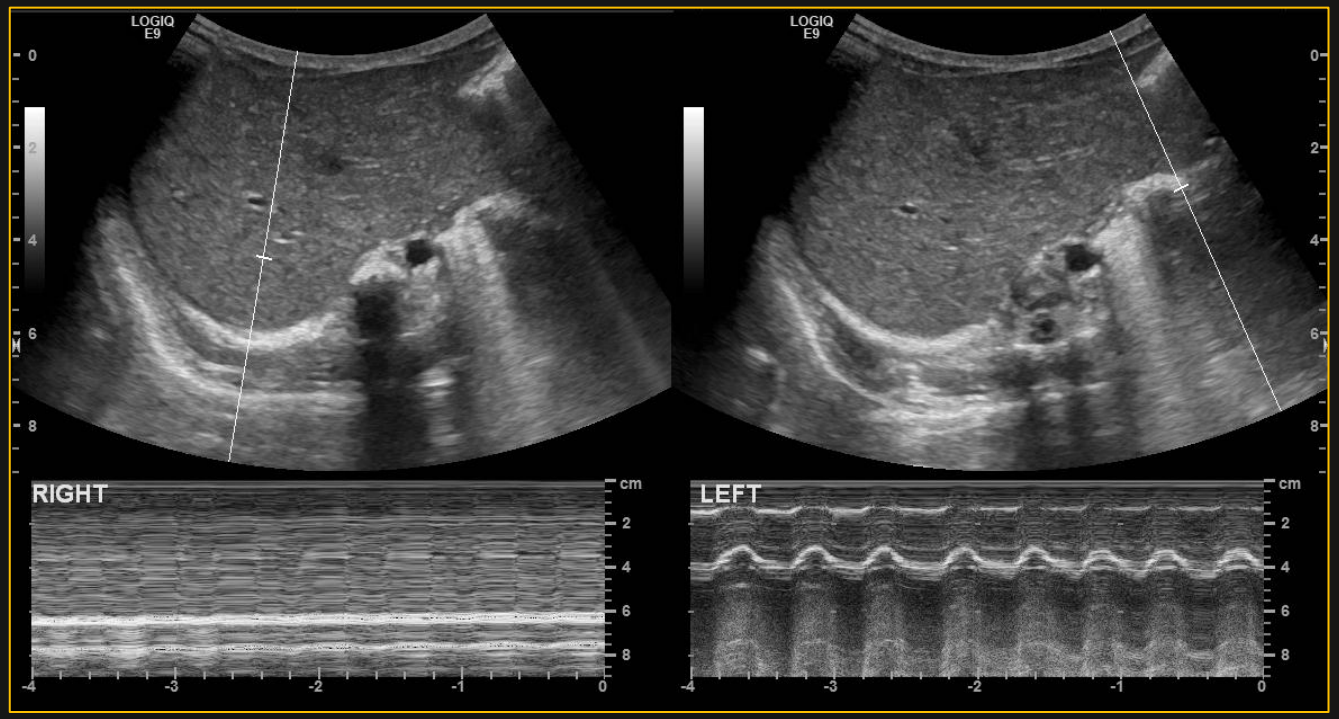
★ Prognostic value : Decreased motion of left dome prior to extubation

Children's National

Absent Motion – Diaphragmatic paralysis

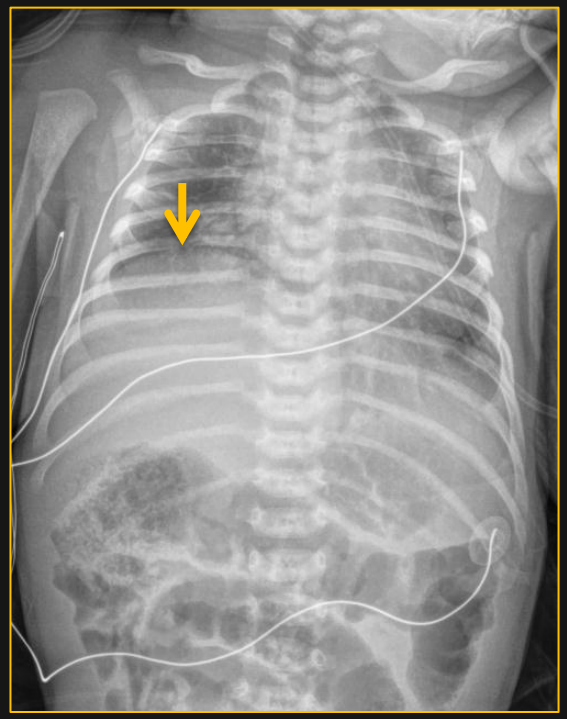
Case 4: 14 day old boy with Erb's palsy

Link to video: https://youtu.be/W7Lhe2kYhO0



Right diaphragmatic paralysis

Normal Left dome

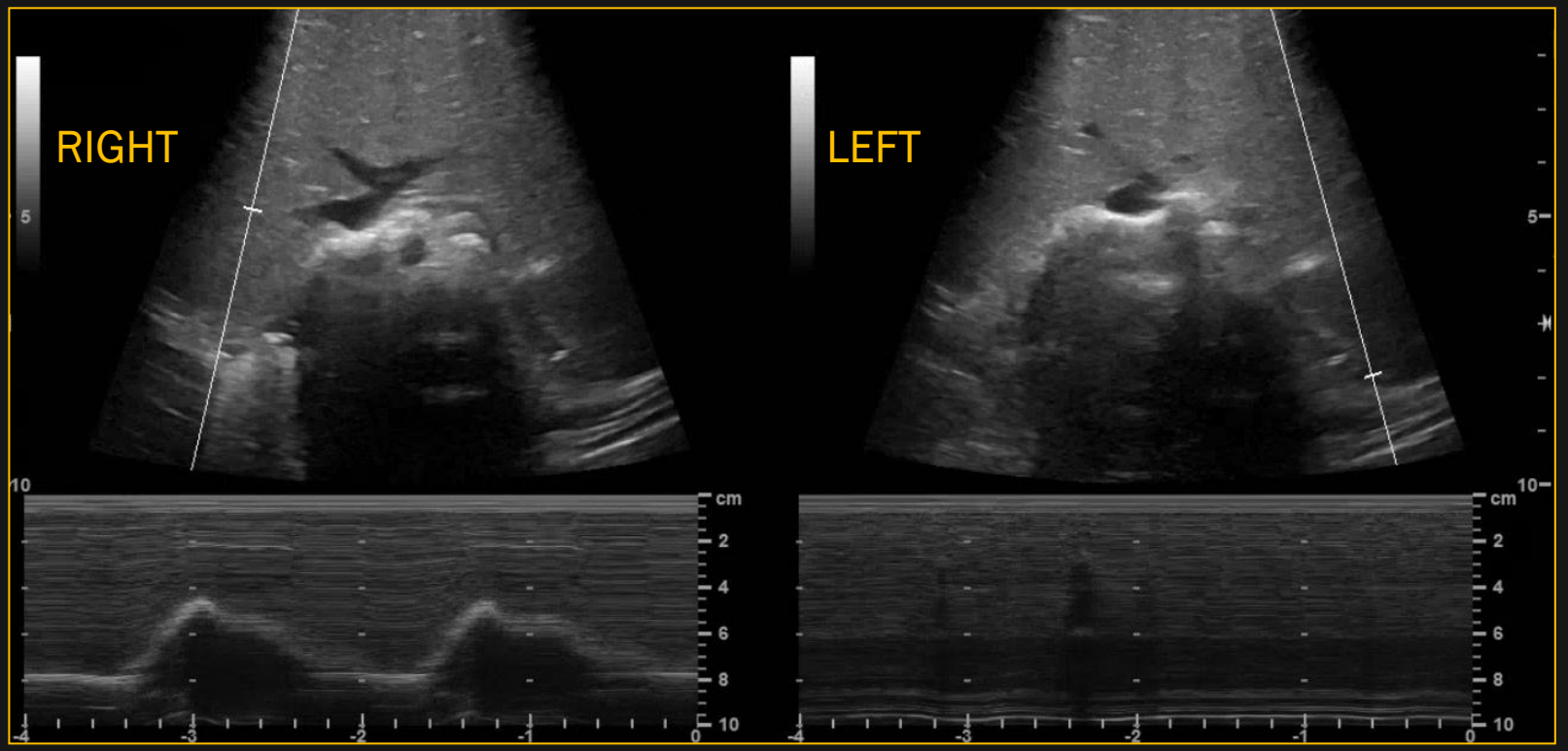


CXR- Rt. Dome elevated

Children's National

Absent Motion – Diaphragmatic paralysis

Case 4: 6 month old unable to wean from ventilator after cardiac surgery



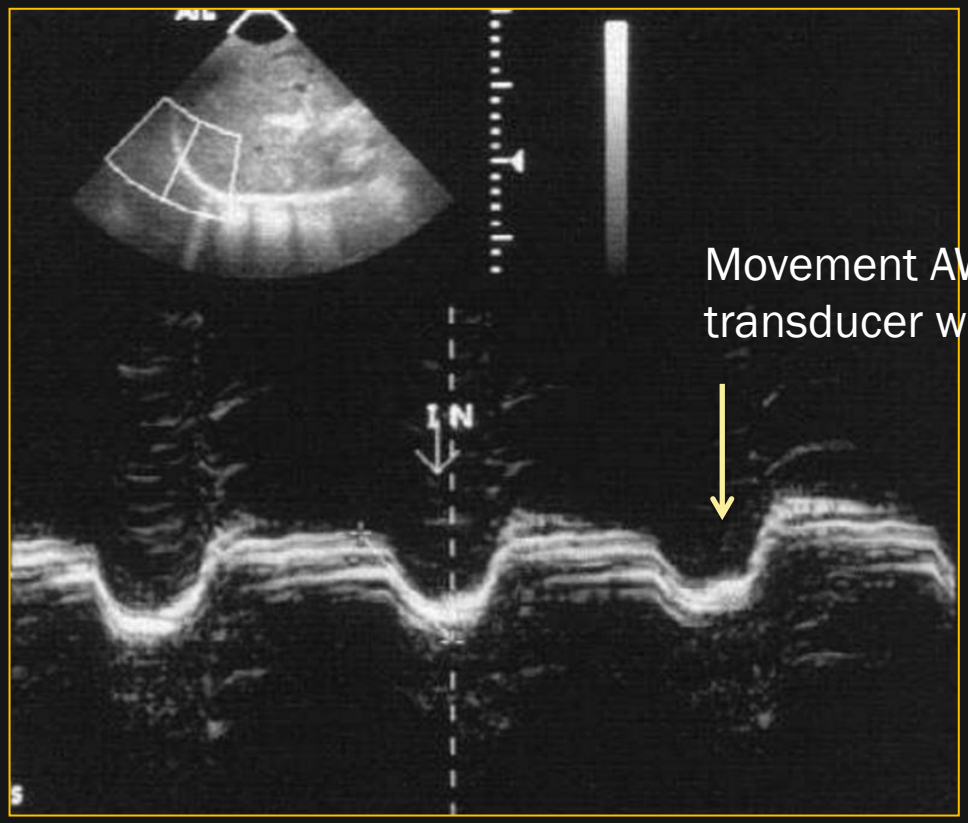
Normal right diaphragm

Left diaphragm paralysis

Children's National

Paradoxical Motion of Diaphragm

Case 5: 12 year old boy with right sided hemiparesis



Movement AWAY from the transducer with Inspiration

Courtesy: Gerscovich et al. J Ultrasound Medicine 20: 597-604, 2001

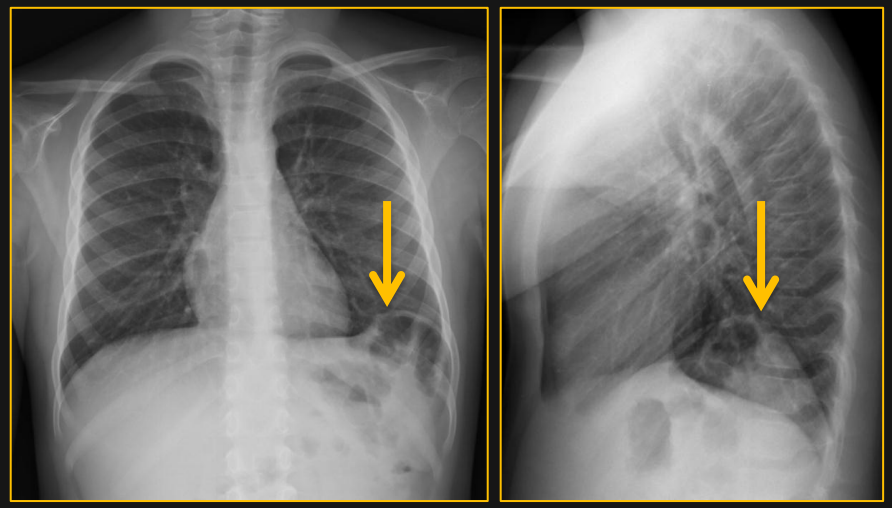
Children's National

Paradoxical Motion of Diaphragm

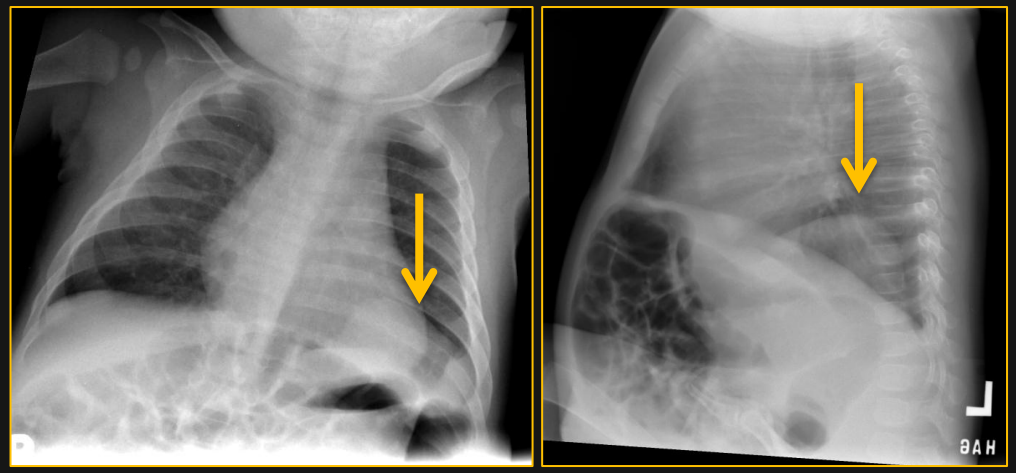
- Opposite of Normal
  - Diaphragm moves AWAY from transducer during INSPIRATION
  - Diaphragm moves TOWARD the transducer during EXPIRATION
- Seen on B-mode and M-mode
- Represents Diaphragmatic Paralysis

Diaphragmatic Eventration

Case 6: 6 year old asymptomatic boy for workup of incidentally noted abnormality on chest radiograph



Contour bulge left diaphragm

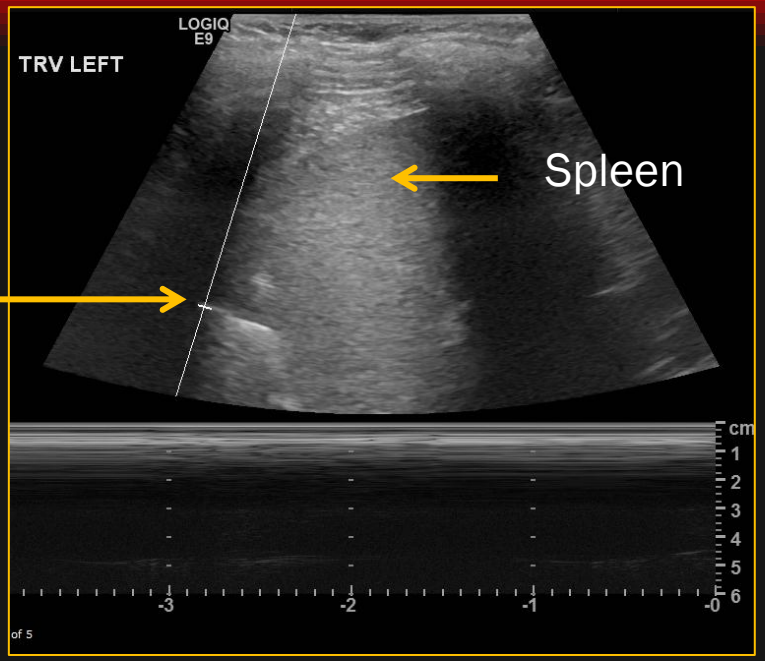


Prior CXR from 3 years ago had showed stable bulge along left dome

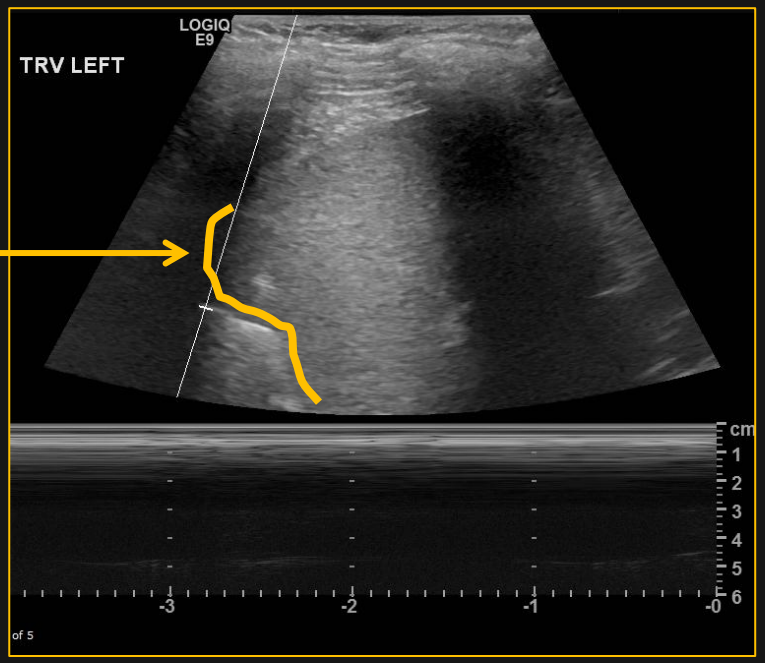
Children's National

Case 6: M-mode

Cursor placed on eventrated portion of left dome



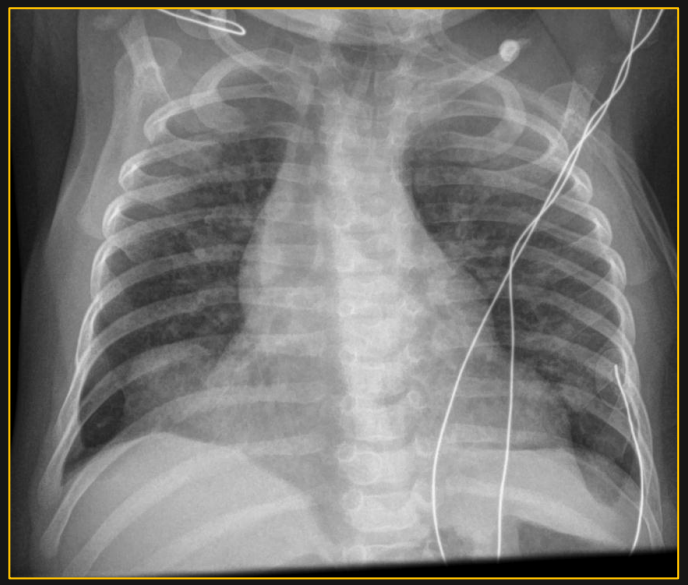
Contour abnormality of left dome

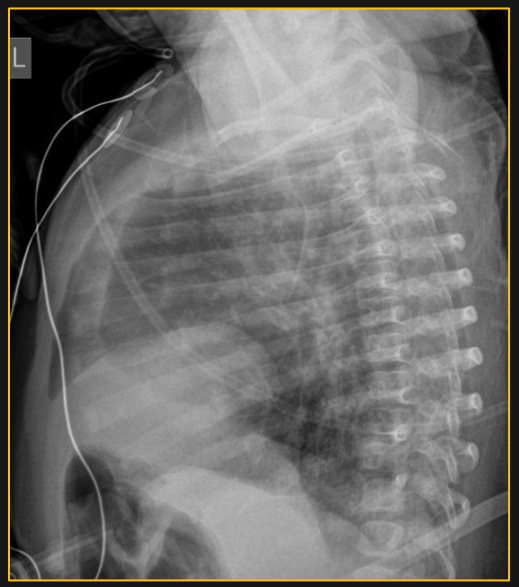


Children's National

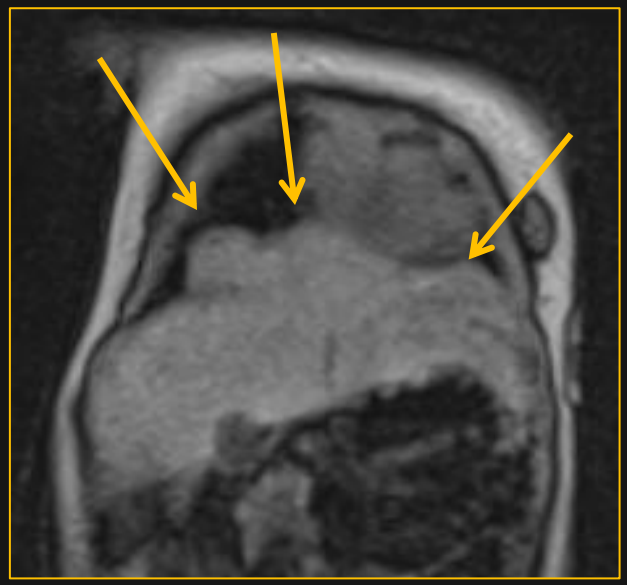
Diaphragmatic Eventration

Case 7: A 5 month old baby with bilateral eventration





Bilateral eventration of diaphragm

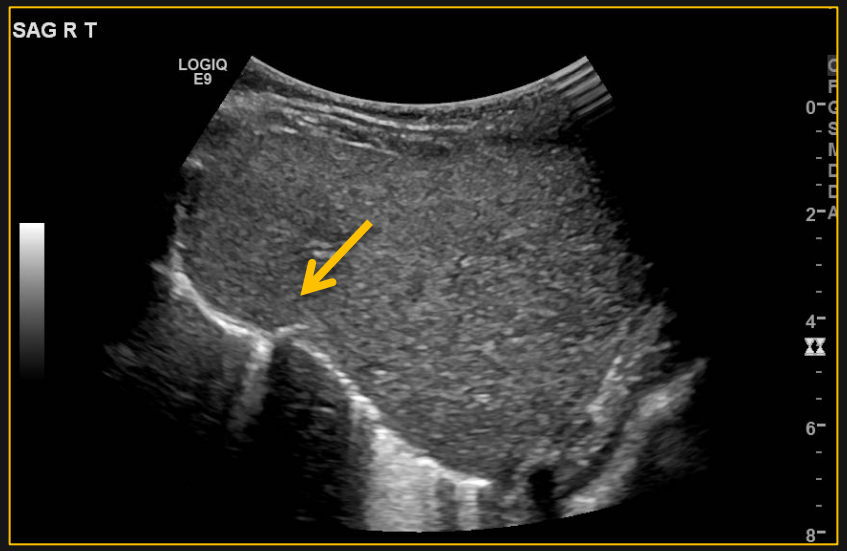


Localizer from cardiac MRI showing the 3 bulges

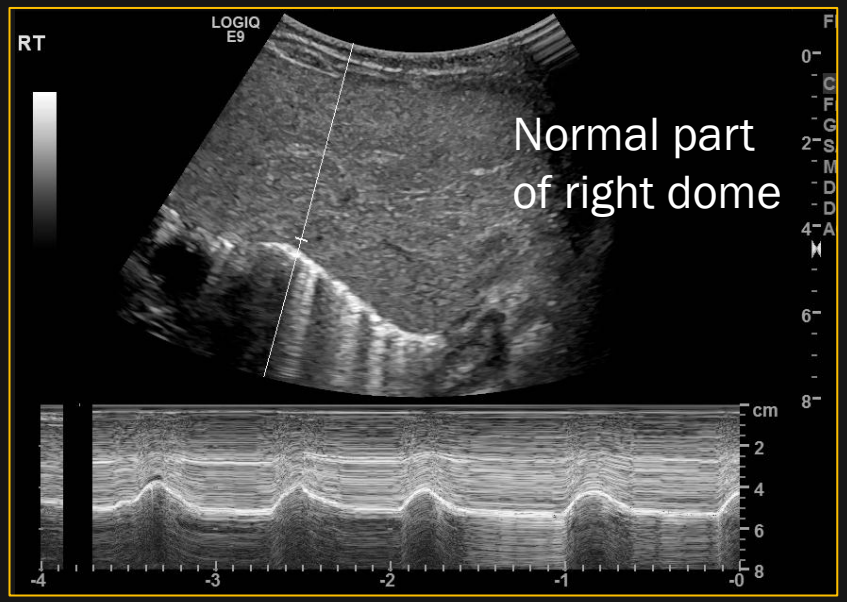
Children's National

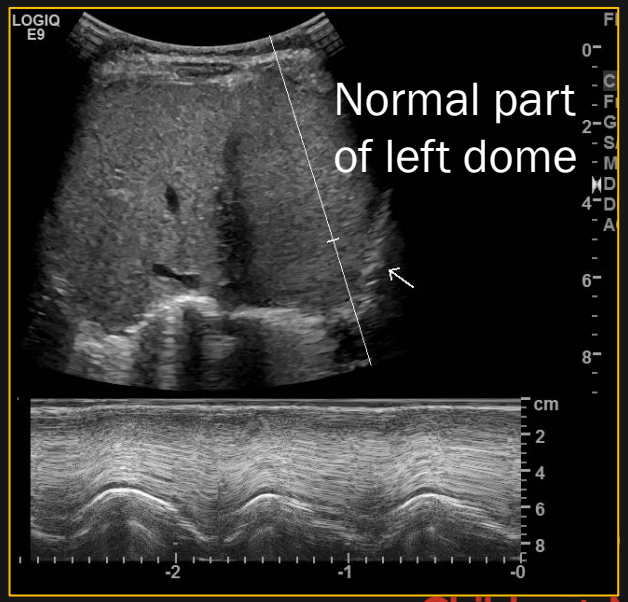
Diaphragmatic Eventration

Case 7:



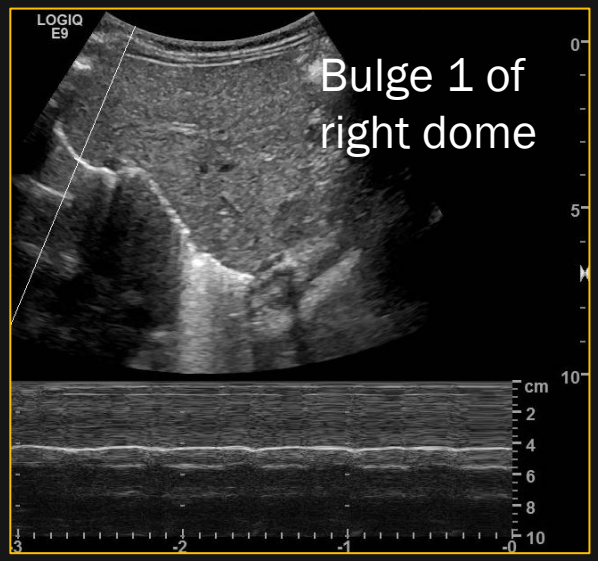
Focal contour bulge along anteromedial part of right dome c/w eventration

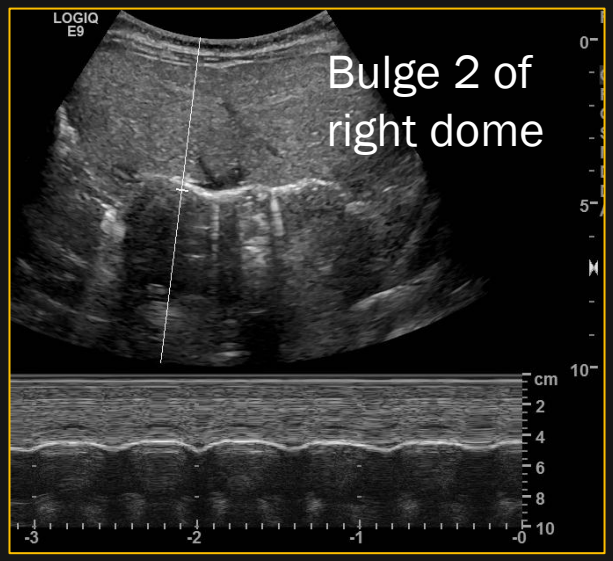


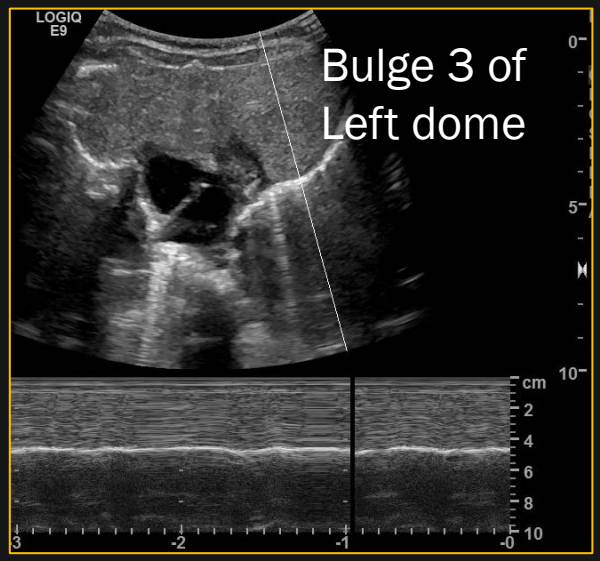


Diaphragmatic Eventration

Case 7: Bilateral eventration





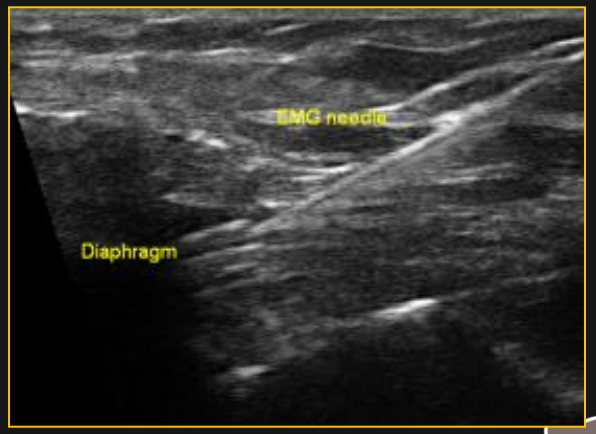


- 3 (2 right and 1 left) ***bulges*** involving the medial hemidiaphragms. The lateral portions of the hemidiaphragms are smooth
- M-mode: Minimal excursion of the 3 ***bulges*** compared to normal lateral hemidiaphragms
- Findings of bilateral medial hemidiaphragmatic eventration without diaphragmatic hernia

Children's National

Treatment

- Diaphragmatic paralysis requires early surgical plication
- Diagnosis of diaphragmatic paresis helps guide therapy to aid in weaning from the ventilator
- Electrical diaphragm stimulation has also been used
  - Reserved for patients with high cervical cord injuries or central hypoventilation syndromes but intact phrenic nerve and diaphragm
  - Allows patients to breath independent of mechanical ventilation
  - Placed under US guidance



- Sarwal A et al. **Muscle Nerve. 2013; 47(3):319-329**
- **Skalsky AJ et al. Phys Med Rehabil Clin N Am 2015; 26:133-143**

Children's National

Conclusions

- Ultrasound using B-mode, M-mode and cine imaging should be the modality of choice for suspected diaphragmatic motion abnormalities
- M-mode sonography quantifies diaphragmatic excursion
- Following a dedicated protocol for diaphragm ultrasound is key to correct diagnosis

Thank You

Author info: dr.ben.xr@gmail.com

anjumnb@gmail.com

Children's National